Cross Enterprise Technology Development Program

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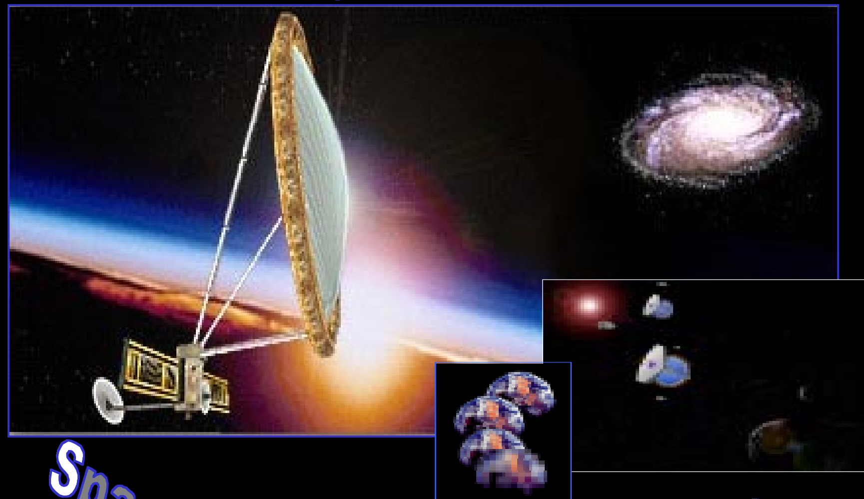
Task Force on Technology Readiness

September 15-17, 1999

NASA Mission

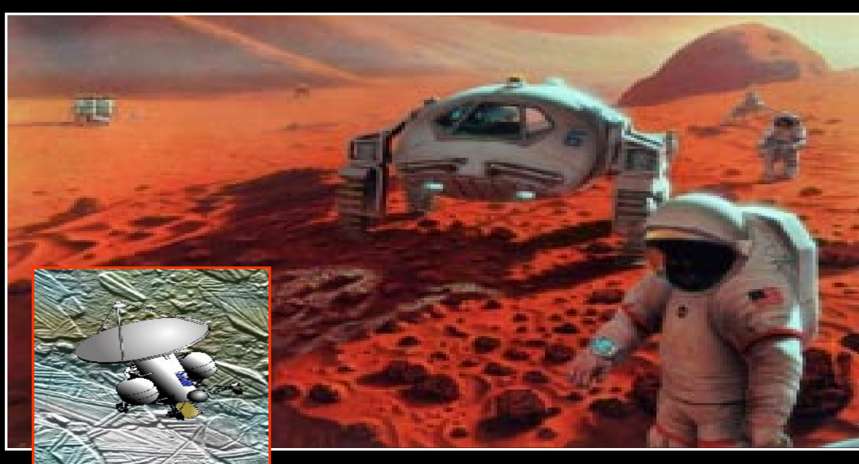
To advance and communicate scientific knowledge and understanding of Earth, the Solar System, and the Universe.



Permanent Human Presence in Space

Space Discovery & Exploration

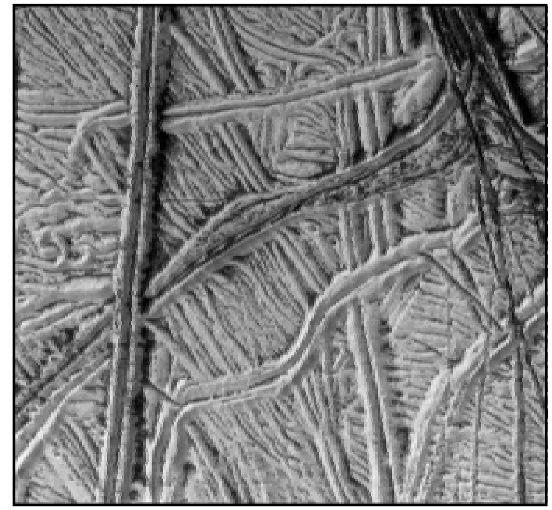
Understanding Earth System Changes



Grand Challenges for NASA

IMAGE AND STUDY PLANETS AROUND OTHER STARS

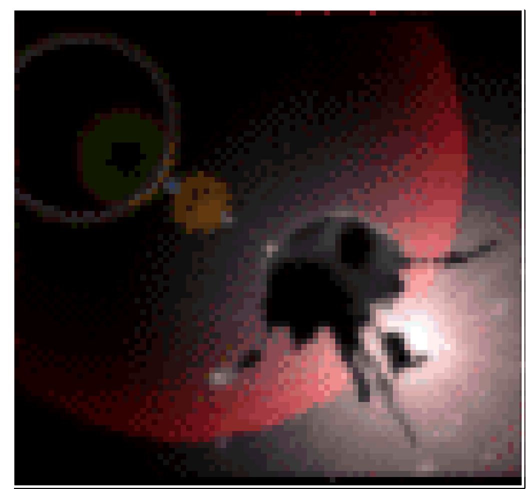
CONDUCT A PROGRESSIVE AND SYSTEMATIC PLAN OF HUMAN EXPLORATION BEYOND EARTH ORBIT



LOOK FOR EVIDENCE OF LIFE ELSEWHERE IN THE SOLAR SYSTEM

READ THE HISTORY AND DESTINY OF THE SOLAR SYSTEM

SEND SPACECRAFT TO A NEARBY STAR



CETDP Program Basics

- CETDP (UPN 632)
  - FY1999 budget in 10 thrust areas ~ $130M
  - Major component of NASA's long term spacecraft technology activities

- Focus on low level, emerging technologies that will have a broad impact across the agency
  - Amortize NASA investment in leading edge technologies by spreading benefits and infrastructure across Enterprises
  - Leverage developments across Enterprises and other government agencies

CETDP Organization

Peter Ulrich, Head
OSS Advanced Technology & MIssion Studies
M. Montemerlo, CETDP Prog. Exec.

Chris Schwartz (GSFC)
CETDP Formulation Office

Steve Prusha (JPL)
CETDP Implementation Office
Chuck Weisbin, Deputy

Kul Bhasin(GRC)
High Rate Data Delivery

Kate Hartman (GSFC)
Distributed Spacecraft

Peter Norvig (ARC)
Thinking Systems

Chris Moore (LaRC)
Ultra Lightweight Structures & Space Obser

Chuck Weisbin (JPL)
Surface Systems

Jerry Housner (LaRC)
Next Generation Infrastructure

Joe Naininger (GRC)
Advanced Power & Propulsion

Jack Stocky (JPL)
Micro Nano Sciencecraft

Tim Krabach (JPL)
Breakthrough Sensors & Instrument Comp

Tri Nguyen (JSC)
Atmospheric Systems & In Space Opera

Thrust Areas

Thrust	Products
Advanced Power and Propulsion	Flight battery, High efficiency solar cell/array technology; energy storage through advance battery designs, flywheel and capacitor technology; electronics thermal control; propellant technology; electric & ion propulsion propulsion; MEMS based propulsion control, advanced thrusters, fuel cells
Atmospherics & In-Space Systems	Obstacle detection (STS), Robonaut technology, Robotic associate, Autonomous Robonauts; Space Operations
Breakthrough Sensors	Microwave components for advanced radar, IR sensitive Thermopiles (uncooled), QUIPS, Pixelated high energy & x-ray detectors; imaging spectrometer; in-situ chemical and biological sample analysis; MEMS technology; micro weather station, advanced laser technology; vibration free coolers.
Distributed Spacecraft	Formation flying hardware and control software, microgyro, GPS on-chip, programmable intelligent micro-tracker, pointing control for formation flying
High Rate Data Delivery	High speed communication devices and protocols; Hyperspectral data mining
Micro/Nano Sciencecraft	Rad-hard electronic devices for miniaturization; MEMS Technology
Next Generation Infrastructure	User interface; collaborative infrastructure; design/simulation tools
Surface Systems	Haptic interfaces, autonomous rover technologies, multiple interacting robots, intelligent robots, virtual environments, sample return
Thinking Systems	Autonomy and on-board science analysis, visualization, knowledge discovery, visual methods for exploration, distributed intelligent agents, human centered autonomous agents, intelligent deployables, self commanding spacecraft
Ultra-Light Structures	Inflatables and deployables; control for deployables; light weight optics, materials for inflatables; space effects, radiation shielding

CETDP Charter is for revolutionary technology

- with a “Pull” component of vetted Enterprise Strategic Tech Req’ts.

- with a “Push” component guided by the TAMs

- with a Core Competence responsibility to the Centers

- with a duty to make use of academia, industry and agencies

- with the responsibility to have as strong positive effect on NASA.

The CETDP Program Develops Two Types of Revolutionary Technology in the Service of NASA and the Enterprises

We develop exciting revolutionary technologies which

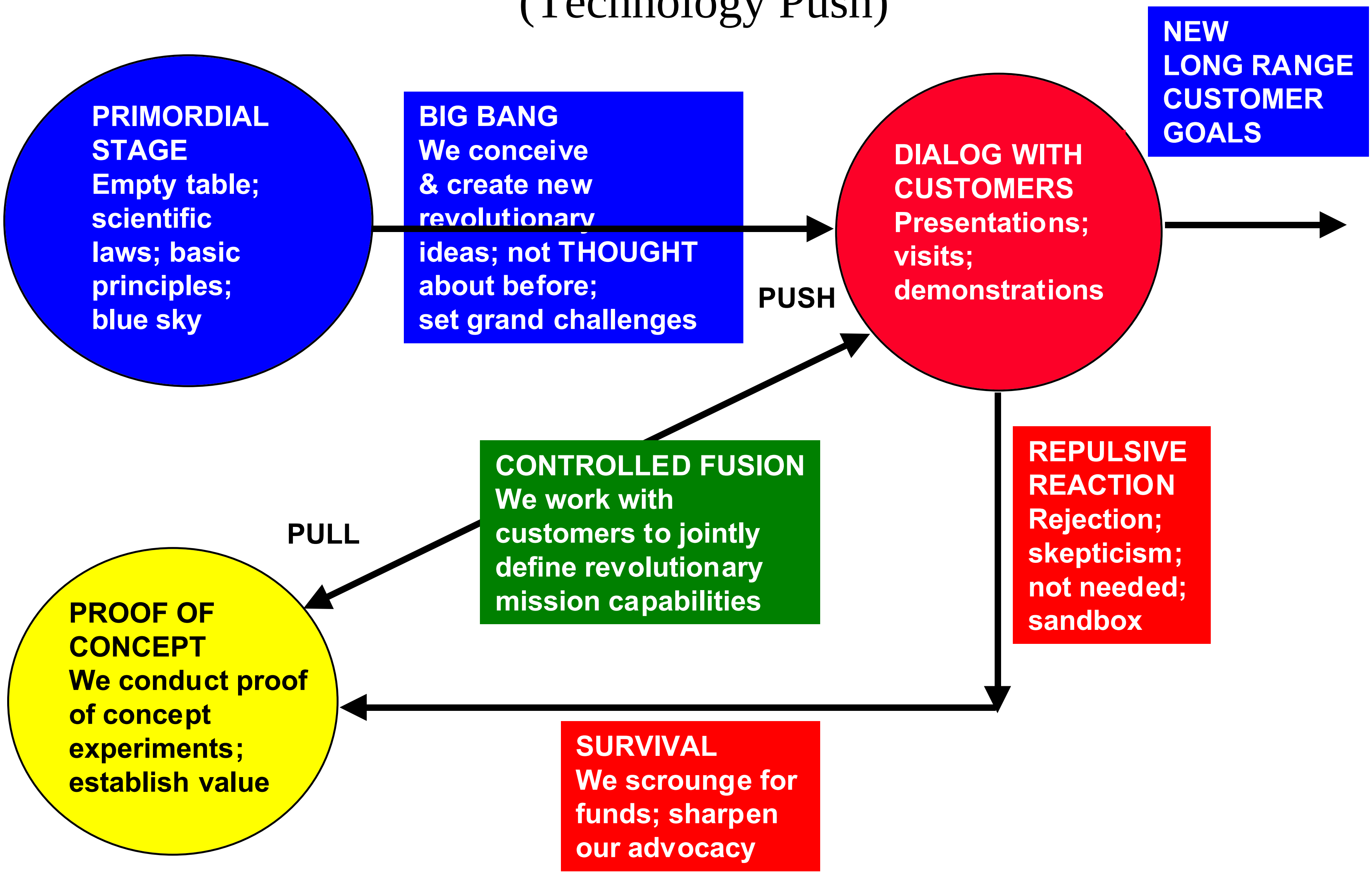
•***PUSH TECHNOLOGIES: Cause the Enterprises to rewrite, improve and expand their Strategic Plans***

- •Technologies that the Enterprises have not yet "bought into"
- •For years, Space Science resisted the use of rovers, but in the mid 1980s, it accepted the large expensive "Mars Rover Sample Return" (MRSR)
- •At that time, Space Science resisted the idea of small rovers, but later, based on UPN 632 research, developed the confidence to make small rovers a central part of their Strategic Plan

•***PULL TECHNOLOGIES: Enable existing Enterprise Strategic Plans***

- •Technologies that the Enterprises have accepted, but that do not yet exist
- •Many visions in the current Enterprise Strategic Plans are wonderfully revolutionary, and many of them were introduced by UPN 632

We Also Create Our Own Revolutionary Challenges and Work with Customers to Create New Long Range Goals (Technology Push)



Inputs to CETDP Come From a Variety of Sources

- Enterprise Requirements and Roadmaps
- Direct Meetings with Code S Theme Directors and codes Y and M Management
- Inter-Agency Committees Plans and Priorities
- Related Program (e.g. SBIR, Explorer) Coordination
- Direction from the Administration and Congress

Our Customer Long Range Challenges are Our Challenges

SPACE SCIENCE

ORIGINS: Precision, ultra-light optics; very large diffraction-limited telescopes

STRUCTURE & EVOLUTION OF THE UNIVERSE: Large ultra light/stable observatories; high-precision formations for VLBI; measure cosmic radiation from faint astronomical sources

SOLAR SYSTEM EXPLORATION: Robust economical colonies of intelligent robots for planetary exploration

SUN EARTH CONNECTION: Solar sails; constellations of autonomous miniature S/C enabled by innovative instruments

EARTH SCIENCE

ADVANCED SENSORS : Discover new events and interactions from unique vantage points of space, aircraft, and in situ platforms

SENSOR WEBS: Respond quickly, intelligently and cost effectively to events in the Earth system

ACCESS TO KNOWLEDGE: Information system architectures for easy access to global information for science, education, and applications

INFORMATION SYNTHESIS: Integrated architectures, to cut cost, and support productive, economical and timely missions

HEDS

OPERATIONS: Enable autonomous operations in support of humans in Space

SCIENCE RESEARCH: Extend scientific discovery and expand scientific knowledge

EXPLORATION: Enable affordable and robust human exploration beyond LEO

HUMAN LIFE SCIENCE: Enable humans to live and work permanently in space

Revolutionary Technology That Has Been Accepted that Does Not Exist

Revolutionary Technology That Has Not As Yet Been Accepted

Cross-Enterprise Technology Development Program Thrusts

- Ultra-Lightweight Structures & Observatories
- Surface Systems
- Breakthrough Sensors
- Thinking Space Systems
- Next Generation Infrastructure
- Power & Advanced Propulsion
- High Rate Data Delivery
- Micro/Nano Spacecraft
- In-Space & Atmospheric Systems
- Thinking Systems

Outputs from the CETDP Are Widely Used

- To: focussed programs in all enterprises for further development and space flight validation
- To: industry for commercialization
- To: other agencies as requested

CETDP Success Stories Apply to Multiple Enterprises

TECHNOLOGICAL SUCCESS STORY	HEDS APPLICABILITY	EARTH SCIENCE APPLICABILITY	SPACE SCIENCE APPLICABILITY
Sojourner & Robotic Sample Return Rovers	Surface Vehicle Mobility; Robotic Assistance to EVA		Wide Area Science; Robotic Outposts;
Ka Band Communications		SATCPOM Industry & Commercial Technology	Deep Space Communications
DS-1 Remote Agent Experiment	Space Vehicle Autonomous Maneuvering	Minimal Maintenance Earth-Orbiting Systems	Deep Space On-Board Navigation
Formation Flying Control Systems	Autonomous Rendezvous Systems	Earth Orbiting Constellations	Precision Telescope Arrays
Cloud Radar ; Weather Station; < mm Wave Detectors & MOMED Mixer		Enable O3 CloudSat Mission; atmosphere OH detectors	Planetary Atmosphere & Weather Surveys
NSTAR Ion Engine & SCARLET PV Array	Ion Propulsion in HEDS Roadmap	Up to 10 KW Applicable to Earth Orbit	Continuous Thrust Deep Space Missions
Hockey Puck Sized Magnetometer Spacecraft		Spacecraft Constellations	>100 S/C Constellations
Precision Deployable & Inflatable Structures		Inflatable Shields for Large Apertures	High-Precision Telescopes

Solar Electric Propulsion Flies on New Millennium DS-1 Mission

Operation of 2.6 KWe ion engine (NSTAR) in space with advanced solar concentration PV array (SCARLET)

- First NASA use of SEP in mission
  - Culmination of years of research
- First application of solar concentrator array
  - Highest efficiency MBG.PV cells ever flown (23%)
  - Increased w/Kg, low cost
- Opens the door for widespread use of electric propulsion
  - Increased mobility
  - Reduced trip times
  - Smaller launch vehicles

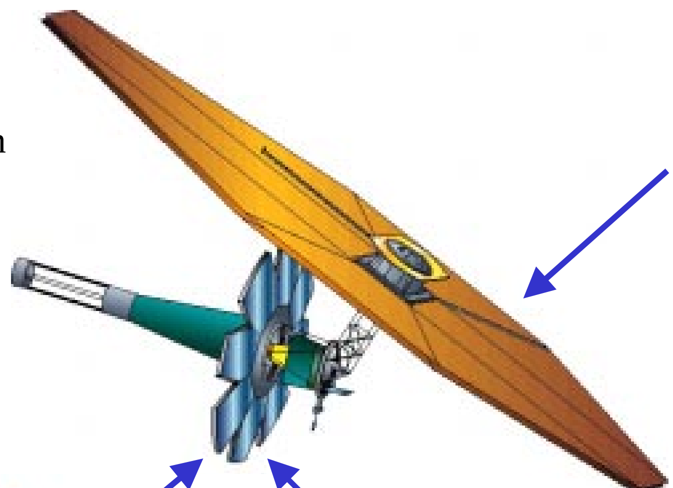
SCARLET

NSTAR

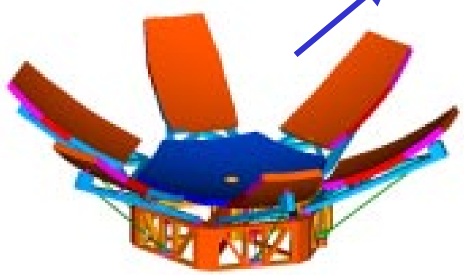
Ultra-Lightweight Structures and Space Observatories Thrust Success Story

CETDP Revolutionary Technology Has Enabled Revolutionary Missions

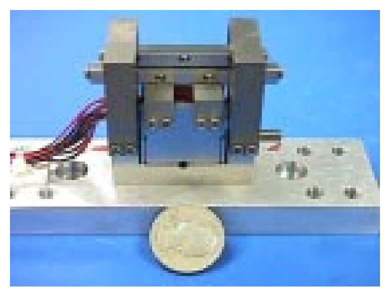
The Next Generation Space Telescope (NGST) will study the origins of galaxies at the edge of the universe. NGST will have 2x greater resolution than the Hubble Space Telescope at infrared wavelengths, and cost 1/4 as much.



Inflatable sunshield developed by CETDP will passively cool telescope to cryogenic temperatures. Inflatable structure enables 10x reduction in launch volume and 2x reduction in sunshield weight. Shown is a 1/2-scale model of the inflatable NGST sunshield.



Precision deployable telescope technology developed by CETDP will enable large apertures to be flown on smaller, lower-cost launch vehicles. Deployable primary mirror enables 3x increase in aperture size. Shown is one petal of a deployable reflector testbed with sub-micron deployment precision.



Cryogenic actuators developed by CETDP will control shape of NGST primary mirror to nanometer precision. Actuators will operate at 30 ^{o}K. Shown is prototype piezoceramic linear actuator.

Surface Systems Thrust Success Story

The Giant Rover that Could

Key Technologies

•Autonomous hazard avoidance & navigation
•6-Wheel rocker-bogie mechanism
• APXS instrument deployment
•Miniaturized rover system

In-Space Robotics Performance

•~100 m traverse
•~15 APXS measurements
•~20 Soil mechanics measurements
•Deployment Maneuver from Lander

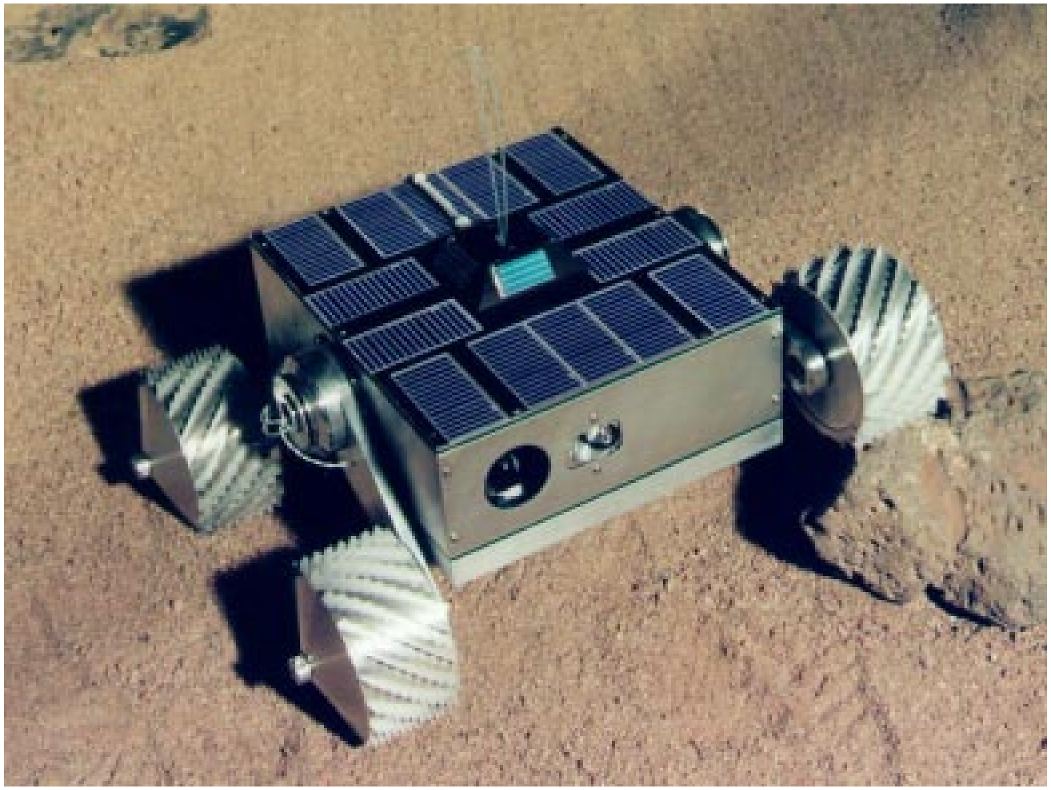
Surface Systems Thrust Success Story

MUSES CN ~1 kg Rover Technology

- NASA Flight Experiment in Muses C Asteroid Mission (02)

- Self-Righting Mechanism

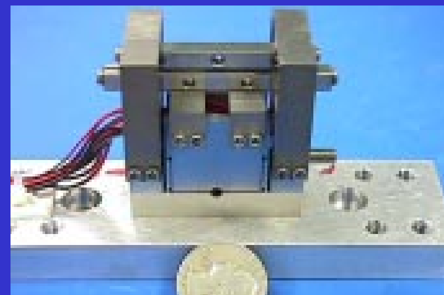
- Embedded Point Spectrometer



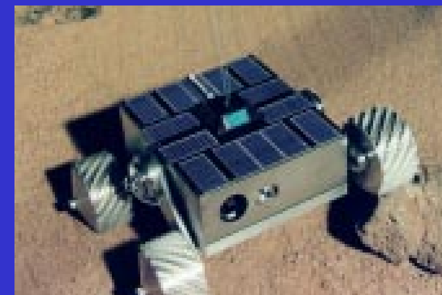
CETDP Products

Enabling customer long range goals.

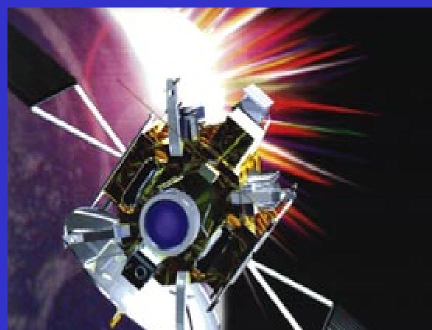
SCARLET



Cryogenic Actuators



MUSES CN 1kg Rover

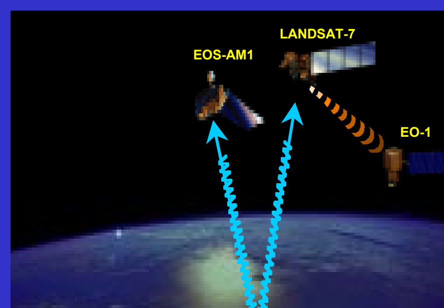


NSTAR

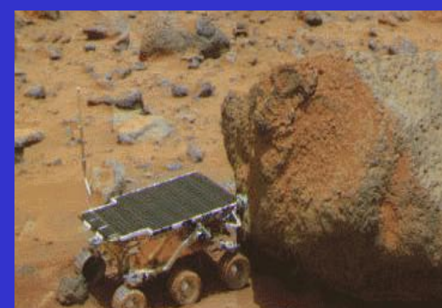
Precision Deployable Telescope

10-Watt, 32-GHz TWTA

Inflatable NGST Sunshield



EO-1 Formation Flying Experiment

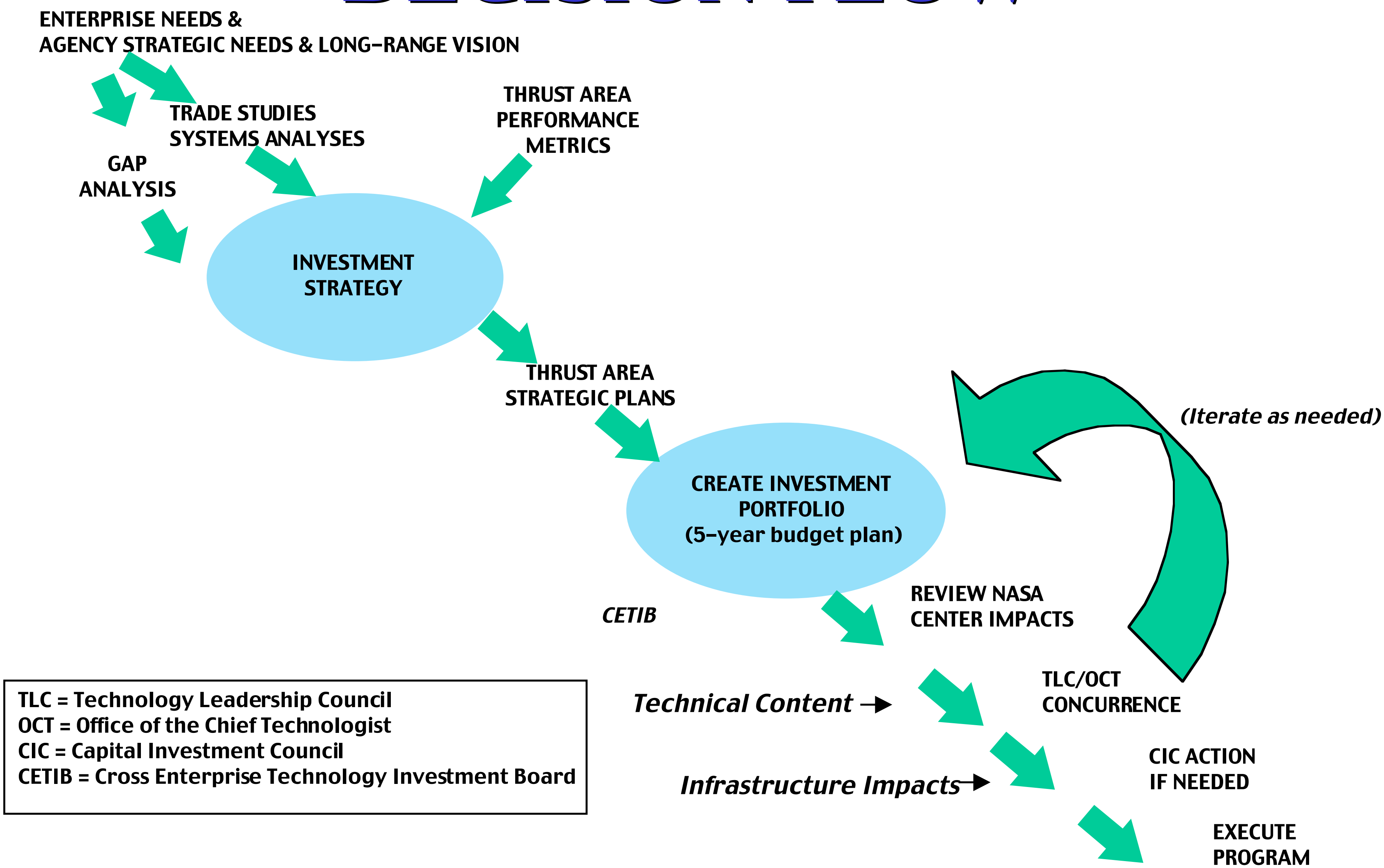


Sojourner 97

Decision Making and Monitoring

- Thrust Area Managers (TAMs) recommend program based on non-advocate technical reviews, enterprise priorities, and Center core competencies
- Internal capability is augmented by external participation through direct contracting and NASA Research Announcements
- TAM performance is monitored by NASA HQ and sponsoring Center.

ANNUAL INVESTMENT DECISION FLOW

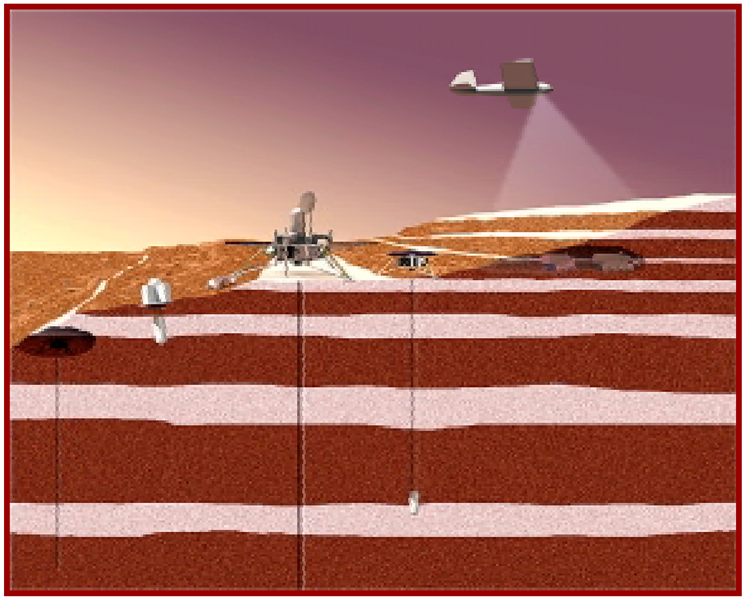


The CETDP Technological Dream is Alive

- Research responds to noble and inspirational goals
  - Zero-uplink deep-space intelligent systems
  - Ultra-deep sub-surface robotic steering and navigation
  - All-access miniature power & propulsion systems
  - High-data rate deep space webs
  - Robot nomads, caravans and heavy duty work crews on planetary surfaces
  - Sense & analyze every ion in the universe
  - > 100 micro/nano spacecraft constellations
  - Ultra-high-precision space telescopes
  - Self-repair and self-reproducing systems

Robotic Outposts: A New Paradigm of Exploration

Mars Polar Terrain Science Laboratory



Elements:

Surface, subsurface, orbiting and airborne investigations

Central labs for analysis/coordination

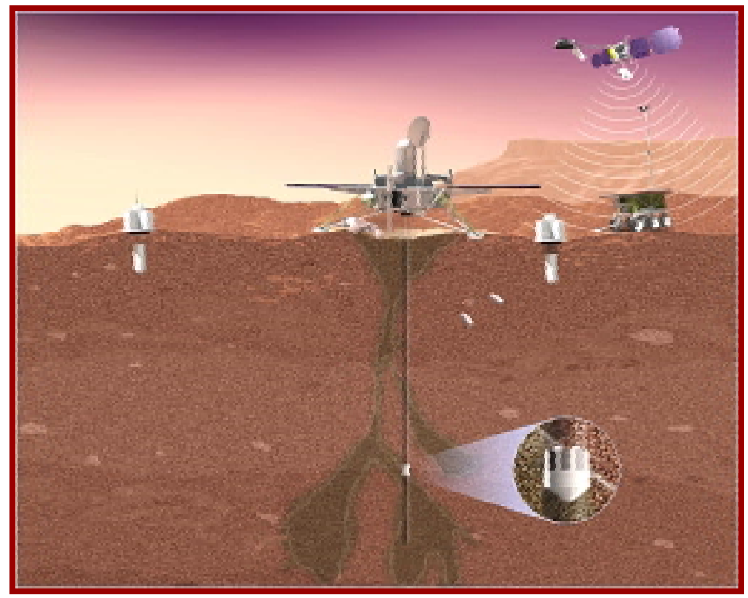
Miniature ascent vehicles

Characteristics:

Distributed robots for wide-area, 3-D exploration and sampling

Ultra-miniature, extended life, expendable/replaceable, adaptable, interactive

Hydrothermal Vent Science Stations



Mars Robotic Outposts and Future Sample Returns

- Surface Systems / Aerial Systems
    - Miniaturized long-life sampling rovers
    - Aerial vehicles - aerobots, airplanes
    - Subsurface sampling and mobility
- Aeroassist
    - Aerocapture and lightweight systems for Mars / Earth entry
- Advanced Power
    - Miniature radioisotope systems
    - Lightweight solar arrays for surface applications
- In situ Sensing Components, In situ Resource Extraction and Processing Components
    - Sample acquisition and handling systems
    - Miniature chemistry and geophysics labs
    - Smart sample identification and selection sensors
- Autonomous Execution and Control
    - Precision landing and hazard avoidance
    - Autonomous surface mobility
    - Interactive spacecraft and goal-directed behavior

Will Our Dreams Materialize?

- Majestic Challenges Facing Us
  - WE picked these challenges “not because they are easy but because they are hard”
  - As we take the long view, WE may never get there
  - Some of the challenges may take generations to overcome
  - Autonomy is easy to conceive but difficult to implement
  - For the foreseeable future, there will be fundamental limits in ways to interact with the environment
  - Human like dexterity, touch, and intelligence are yet to be matched
  - Much revolutionary technology is in its infancy (e.g. Sojourner)
  - Stakeholders (sponsors, public, everyone) may lose patience and cut budgets